(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) Publication number : **0 486 147 B1**

(12) **EUROPEAN PATENT SPECIFICATION**

(45) Date of publication of patent specification : **13.12.95 Bulletin 95/50**

(51) Int. Cl.^{6} : **H01J 27/22**, H01J 27/02, H01J 27/08

(21) Application number : **91309008.0**

(22) Date of filing : **02.10.91**

(54) Ion beam generating apparatus with electronic switching between multiple cathodes

(30) Priority : **14.11.90 US 612589**

(43) Date of publication of application : **20.05.92 Bulletin 92/21**

(45) Publication of the grant of the patent : **13.12.95 Bulletin 95/50**

(84) Designated Contracting States : **AT BE CH DE DK ES FR GB GR IT LI LU NL SE**

(56) References cited :
EP-A- 0 282 677
EP-A- 0 300 566
EP-A- 0 307 017
US-A- 2 682 611

(73) Proprietor : **ISM TECHNOLOGIES, INC.**
9965 Carroll Canyon Road
San Diego, California 92131 (US)

(72) Inventor : **Magnuson, Gustav D.**
1755 Catalina Boulevard
San Diego, California 92107 (US)
Inventor : **Tooker, Joseph F.**
10364 Pinecastle Street
San Diego, California 92131 (US)
Inventor : **Treglio, James R.**
12202 Spruce Grove Place
San Diego, California 92131 (US)

(74) Representative : **Lerwill, John et al**
A.A. Thornton & Co.
Northumberland House
303-306 High Holborn
London, WC1V 7LE (GB)

EP 0 486 147 B1

Description

This invention relates in general to devices for generating metallic ion beams and, more particularly, to an ion beam generator which is capable of switching among a plurality of cathodes and to a cathode assembly for use in such an ion beam generator.

A number of different devices have been developed for generating metallic ion beams. One system, as described in US-A- 3,566,185 uses a pair of parallel cathodes spaced from a slit anode. The cathodes are at the same negative potential with respect to the anode. Electrons which are created by the ionization of gas atoms are accelerated toward the anode, but are constrained by the magnetic field and oscillate between the cathodes. Positive ion bombardment sputters material from the cathode to form a plasma from which ions move through the anode slit as a metallic ion beam. This system tends to have relatively low ion current and changing the cathodes to change the metal being ionized is slow and time consuming, requiring release of the vacuum, replacing cathodes and restoring the chamber vacuum.

Brown in U.S. Patent 4,714,860 describes an ion beam generating apparatus. A cathode constructed from the metal to be used as the source of ions is placed in a vacuum chamber spaced from an anode having a single central opening. An electrical potential is imposed between anode and cathode. An electrical arc is generated between anode and cathode, vaporizing a portion of the cathode and forming a metal ion plasma which is moved by a magnetic field toward and through the anode opening toward a target. While this apparatus will produce an effective ion beam, in order to change the metal being transmitted requires substantial disassembly of the apparatus, with release and reformation of the vacuum required. Only a single cathode may be used, aligned with the anode opening. Also, as the cathode erodes with use, efficiency falls off to the point at which the assembly must be disassembled for cathode replacement.

Attempts have been made to incorporate plural cathodes on a rotatable turret so that cathodes of different metals or new cathodes could be rotated into alignment with the anode opening when a cathode is worn or a different metal is desired. However, problems arise with leakage at seals between the rotatable turret and the vacuum chamber, the cathodes not in use may interact with the one in use and alignment with a narrow anode opening may not be precise.

EP-A-307 017 discloses an array of parallel cathodes, a common anode and a common trigger electrode for starting all the discharges simultaneously, while EP-A-300 566 discloses an array of cathode-anode cells started by a cathode/electrode trigger assembly. However, there is a continuing need for improved ion beam generating devices capable of rapid and convenient switching between cathodes without impairing vacuum integrity of the system, capable of compensating for erosion of a cathode during use and capable of operating without precise cathode to anode opening orientation and having reduced mechanical and manufacturing complexity.

It is, therefore, an object of this invention to provide an ion beam generating apparatus which overcomes the above-noted problems.

Another object is to provide an ion beam generating apparatus which is capable of rapid electronic switching among a plurality of cathodes.

A further object is to provide an ion beam generating apparatus having an anode which does not require the cathode to always be located in one operating position.

Yet another object of the invention is to provide an ion beam generating apparatus having more reliable triggering of the cathodic arc, increased beam current, longer permissible pulse operation periods and increased arc efficiency.

Still yet another object is to provide an ion beam generating apparatus in which cathodes may be continuously fed into place to accommodate cathode erosion during beam generation.

According to one aspect of the invention there is provided an ion bean generating apparatus comprising a generally tubular housing closed at the first end by a first plate and at the second end by a second plate, a plurality of cathodes within said housing mounted on said first plate, said cathodes arranged in a substantially parallel array extending toward said second plate, a high transparency screen anode mounted in an opening in said second plate, said anode lying substantially parallel to said cathode array and substantially coextensive with said array, and at least one trigger cathode and trigger electrode assembly positioned adjacent to said array and extending into said housing.

According to another aspect of the present invention there is provided a cathode assembly for an ion beam generating apparatus, said cathode assembly comprising an array of spaced rod-like cathodes each having an ion beam producing end, a trigger cathode and trigger electrode assembly adjacent to said cathode array, said trigger cathode and trigger electrode assembly comprising, a rod-like metal trigger cathode extending toward said array, an insulating sleeve around said trigger cathode, a metal sleeve around said insulating sleeve, and a trigger electrode adjacent to said trigger cathode, whereby said trigger electrode assembly can initiate an arc at any cathode in said array that is at suitable potential level.

Other features and attendant advantages of the present invention will become apparent to those skilled in the art from a reading of the following detailed description constructed in accordance with the drawings.

Details of the invention, and of preferred embodiments thereof, will be further understood upon reference to the drawings, wherein:

Figure 1 is a schematic section view through the apparatus of this invention, taken substantially on the centerline of the substantially cylindrical apparatus;

Figure 2 is a schematic section view taken on line 2--2 in Figure 1, basically showing an end view of the cathode array;

Figure 3 is a schematic axial section view through a typical prior art cathode; and

Figure 4 is a schematic detail view of a cathode feeding mechanism.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

The ion beam generating apparatus 10 as seen in Figures 1 and 2 would, in use, be vacuum-tight and connected to a conventional vacuum chamber 11, a portion of which is schematically indicated. This invention involves only the apparatus for generating an ion beam. The remainder of the over-all metal plating structure, including cooling means, target holder, vacuum chamber, etc. may be any conventional structure as used in present commercial devices as are well known to those skilled in the art. A first cylindrical housing 14 is mounted to the chamber 11 by a first ring 12. A second generally tubular housing 15 is mounted on plate 16 which is in turn secured to housing 14 through ring 17. These components are secured together by a plurality of conventional fasteners, such as the schematically indicated bolts 18. Not all bolts are shown, some being hidden in this view. A cathode support plate 22 is secured to the distal end of housing 15.

A plurality of cathodes 26 are mounted on base plate 22. Typically, the array of cathodes may be in the form of a ring arrangement with one cathode in the center, as seen in Figure 2. Typical cathodes comprise a copper body which is electrically insulated from base plate 22 and carries the metal to be ionized at the other end. Any suitable cathode configuration may be used. Solid copper cathodes could carry the metal 28 to be ionized as a block or cylinder at the end of the copper body.

Alternatively, the metal 28 could be a long cylinder slidably supported within a sleeve 30, as schematically indicated in Figure 1. In that case, the metal 28 could extend through plate 22 into a drive mechanism schematically indicated, shown in Figure 4 and described below.. Any suitable linear drive, such as the preferred mechanism illustrated, could be used to move metal cylinder 28 into the apparatus at the rate it is consumed. Such a cathode feed mechanism can extend cathode life to 40 hours or more.

A trigger cathode assembly 30 is provided to trigger ionization of any of the plural cathodes 26. Trigger cathode assembly 30 is mounted on a base plate 32 and housed within a tube 34 connected to housing 15. A trigger electrode 36 is spaced from trigger cathode 38 and connected to a conventional pulse transformer (not shown) through connector 40. Trigger cathode 38 includes a metal core 42, typically copper, surrounded by an electrically insulating sleeve 44 and a metal sleeve 46.

A pulse of about 10 to 20 kilovolts initiates an arc between cathode 42 and metal ring 46. The pulse has a pulse length typically of about 100 microseconds. An arc spot is formed on the end of cathode 42 where the current density may be as high as 10-100 million amperes per square centimeter. This current density is sufficient to vaporize, and essentially completely ionize, a small amount of cathode material. The metal plasma thus created has a directed velocity away from trigger cathode 42 and toward the array of cathodes 26. The cathode which is to be fired is given a potential difference between the selected cathode 26 and adjacent screen anode 48 (mounted in ring 50 as detailed below) of about 50 volts. The other cathodes 26 remain electrically floating. The pulse can be electronically switched to any other cathode 26 simply by connecting that cathode to the 50 volt potential and electrically floating the original cathode. The plasma pulse from the trigger cathode 38 provides the conductive path from selected cathode 26 to screen anode 48, thus eliminating the need for a trigger ring and insulator on the ends of each cathode 26 of the sort provided at 44 and 46 with trigger assembly 30.

An anode 48 in the form of a high-transparency metal screen is mounted on tube 50 near the ends of cathodes 26. Tube 50 is carried on the ring 16. Any suitable screen may be used, such as a finely perforated metal sheet or a woven screen. Preferably, from about 30 to 75 % of the screen is open. Copper is preferred for screen anode 48 due to its excellent thermal conduction and electrical and physical properties. This screen is greatly superior to the anodes of the prior art which use a single central hole for passage of the ion stream. With single aperture anodes it is sometimes difficult to get the arc to transfer from cathode to anode, particularly in the case of low vapor pressure cathode materials. With the screen anode, cathodes do not need to be located at the precise center of the anode opening, permitting the variable cathode positioning shown in Figures 1 and 2. Screen anode 48 and tube 50 are mounted on ring or second plate 16 with the anode parallel to and spaced from the array of cathodes 26 mounted on the first ring or plate 22.

Changing from one cathode to another is merely a matter of electrically floating the other cathodes. It is an easy matter to fire any one cathode, or several, at one time. The elimination of movement of plural cathodes on a turret or the like has many advantages, including the speed with which cathodes can be changed and the elimination of vacuum seals and other mechanisms.

The plasma passes through screen anode 48 and moves to an extractor region where a plurality of grids 51 extract ions and move them on toward a target in a conventional manner.

With auxiliary triggering through trigger cathode assembly 38 the need for individual trigger means at each cathode is eliminated. Triggering is more reliable, longer pulse operation (>1 msec) is allowed and the average beam current can be increased.

Prior art cathodes corresponding to our cathode 26 were generally of the sort shown in Figure 3. Here, the cathode 52 required an insulating ring 54 around the operating end, with a metal trigger ring 56 surrounding the insulating ring. With those cathodes, the arc is initiated by applying a pulse of high voltage to the trigger ring. An arc spot is formed on the cathode end at a current density sufficient to vaporize a small amount of cathode material. The metal plasma from that arc filled the space between the cathode and an adjacent single aperture anode. The arc then transfers to the anode due to a potential difference between cathode and anode. The arc is sustained between cathode and anode for about 1 millisecond, after which it is extinguished and the entire process is repeated anywhere from about 1 to 100 times per second. The plasma flows through the circular aperture in the anode and drifts toward an extractor region where the ions are extracted by a multi-aperture grid, to produce the energetic ion beam.

Arc initiation with the prior art cathode arrangement is dependent on the presence of a conductive path across the insulator 54. This conductive path is provided by metal deposition from cathode 52 onto insulator 54. With too much metal deposition, the trigger voltage can be shorted out, causing failure of arc initiation. With too little deposition of metal on insulator 54, arc initiation again fails. One of the important factors that controls the amount of metal deposition is the vapor pressure of the material of cathode 52. Thus, arc initiation reliability can vary widely from one cathode material to another, a serious problem with these prior art cathodes. Also, pulse length is limited with these prior art cathodes, since at long pulse lengths (greater than about 1 millisecond) metal deposition becomes too severe, shorting out the trigger voltage in a very short time. The system of this invention, on the other hand, eliminates variable metal deposition problems by eliminating the insulating sleeve 54 and trigger ring 56, so that cathodes of metals having widely varying vapor pressures may be used permitting long pulse length operation (typically greater than 10 milliseconds). The longer pulse length results in an increased duty cycle, higher average beam current and greater arc efficiency. Also, with the elimination of insulator 54, insulator debris formation during operation is eliminated.

In order to lengthen cathode lifetime, we provide a linear drive mechanism as shown in detail in Figure 4 to move each cathode 28 or 38 forward as the end is consumed. The drive mechanisms are located in a housing 62 as seen in Figure 1. Each cathode 26 and 38 has a metal rod 28 and 42, respectively, slidable in an outer sleeve which may be an insulating material insulating the metal cathode from the housings. As seen in Figure 4, a linearly movable cathode rod 64 is connected by any suitable means to the base of each cathode rod 28 and/or 42 for movement as indicated by arrow 66. An arm 60 connects rod 64 to a nut 68 threadably engaging lead screw 70. Lead screw 70 is mounted on a pillow block 72 at one end and a gear 74 at the other. A stepper motor 76 drives gear 74 through gear 78. Thus, a cathode can be moved forwardly as cathode material is consumed, then rearwardly to replace a worn cathode with a new or a different cathode. Conventional sensors may sense cathode erosion and operate stepper motor 76 to automatically compensate therefor, or cathode movement may be controlled manually, as desired.

While certain preferred arrangements, dimensions and materials were detailed in the above description of preferred embodiments, those can be varied, where suitable, with similar results. Other variations, ramifications and applications of this invention will occur to those skilled in the art. Those are intended to be included within the scope of the claims.

Claims

1. An ion beam generating apparatus (10) comprising:

   a generally tubular housing (15) closed at the first end by a first plate (22) and at the second end by a second plate (16);

   a plurality of cathodes (26) within said housing mounted on said first plate (22), said cathodes arranged in a substantially parallel array extending toward said second plate (16);

   a high transparency screen anode (48) mounted in an opening in said second plate, said anode (48) lying substantially parallel to said cathode array and substantially coextensive with said array; and

   at least one trigger cathode (38) and trigger electrode assembly (36) positioned adjacent to said array and extending into said housing (15).

2. The ion beam generating apparatus according to claim 1, further including linear feed means (61) for selectively feeding selected ones of said cathodes (26) toward said anode (48).

3. The ion beam generating apparatus according to

claim 1 or claim 2, further including linear feed means (62) for selectively feeding said trigger cathode (38) toward said array.

4. The ion beam generating apparatus according to any of claims 1 to 3, wherein said anode screen (48) area has from about 30 to 75% openings.

5. An ion beam generating apparatus according to claim 1, wherein the ends (28) of said cathodes making up said array and extending toward said second plate (16) lie substantially in the same plane, and said trigger electrode assembly (36) is capable of initiating an arc at any selected ones of said cathodes (26).

6. A cathode assembly for an ion beam generating apparatus, said cathode assembly comprising;
an array of spaced rod-like cathodes (26) each having an ion beam producing end (28);
a trigger cathode and trigger electrode assembly (30) adjacent to said cathode array;
said trigger cathode and trigger electrode assembly (30) comprising:
a rod-like metal trigger cathode (42) extending toward said array;
an insulating sleeve (44) around said trigger cathode (42);
a metal sleeve (46) around said insulating sleeve (44); and
a trigger electrode (36) adjacent to said trigger cathode (42);
whereby said trigger electrode assembly (36) can initiate an arc at any cathode (26) in said array that is at suitable potential level.

7. The cathode assembly according to claim 6, further including linear feed means (61) for selectively feeding selected ones of said cathodes (26) toward said ion beam producing end (28).

8. The cathode assembly according to claim 6 further including linear feed means (62) for selectively feeding said trigger cathode (42) toward said array.

9. The cathode assembly according to claim 6 wherein said cathodes (26) making up said array are substantially parallel to each other and the trigger cathode (42) axis lies in a plane which is substantially perpendicular to the axes of said cathodes (26).

Patentansprüche

1. Eine Ionenstrahlerzeugungsvorrichtung (10), umfassend:
ein allgemein rohrförmiges Gehäuse (15), das an dem ersten Ende durch eine erste Platte (22) und an dem zweiten Ende durch eine zweite Platte (16) geschlossen ist;
eine Vielzahl von Kathoden (26) in dem genannten Gehäuse, die an der genannten ersten Platte (22) angebracht sind, wobei die genannten Kathoden im wesentlichen in einer parallelen Vielfachanordnung angeordnet sind, die sich in Richtung zu der genannten zweiten Platte (16) erstreckt;
eine hochtransparente Schirmanode (48), die in einer Öffnung in der genannten zweiten Platte angebracht ist, wobei die genannte Anode (48) im wesentlichen parallel zu der genannten Kathodenvielfachanordnung und im wesentlichen in gleichem Umfang mit der genannten Vielfachanordnung liegt; und
mindestens eine Auslösekathode (38) und eine Auslöse-elektrodeneinrichtung (36), die der genannten Vielfachanordnung benachbart angeordnet ist und sich in das genannte Gehäuse (15) erstreckt.

2. Die Ionenstrahlerzeugungsvorrichtung gemäß Anspruch 1, die ferner eine lineare Zuführvorrichtung (61) einschließt, um wahlweise ausgewählte der genannte Kathoden (26) in Richtung zu der genannten Anode (48) zuzuführen.

3. Die Ionenstrahlerzeugungsvorrichtung gemäß Anspruch 1 oder Anspruch 2, die ferner eine lineare Zuführvorrichtung (62) einschließt, um wahlweise die genannte Auslösekathode (38) in Richtung zu der genannten Vielfachanordnung zuzuführen.

4. Die Ionenstrahlerzeugungsvorrichtung gemäß irgendeinem der Ansprüche 1 bis 3, in der die Fläche des genannten Anodenschirms (48) von ungefähr 30 bis 75 Prozent Öffnungen aufweist.

5. Eine Ionenstrahlerzeugungsvorrichtung gemäß Anspruch 1, in der die Enden (28) der genannten Kathoden, die die genannte Vielfachanordnung bilden und sich in Richtung zu der genannten zweiten Platte (16) erstrekken, im wesentlichen in derselben Ebene liegen, und wobei die genannte Auslöseelektrodeneinrichtung (36) einen Entladungsbogen bei irgendeiner ausgewählten der genannten Kathoden (26) auslösen kann.

6. Eine Kathodenvorrichtung für eine Ionenstrahlerzeugungsvorrichtung, wobei die genannte Kathodenvorrichtung umfaßt:
eine Vielfachanordnung beabstandeter, stangenförmiger Kathoden (26), von denen jede ein einen Ionenstrahl erzeugendes Ende (28) hat;

eine Auslösekathoden- und Auslöseelektrodenvorrichtung (30), die der genannten Kathodenvielfachanordnung benachbart ist;

wobei die genannte Auslösekathoden- und Auslöseelektrodenvorrichtung (30) umfaßt:

eine stangenförmige Metallauslösekathode (42), die sich in Richtung zu der genannten Vielfachanordnung erstreckt;

eine Isolierhülse (44) um die genannte Auslösekathode (42) herum;

eine Metallhülse (46) um die genannte Isolierhülse (44) herum; und

eine Auslöseelektrode (36), die der genannten Auslösekathode (42) benachbart ist;

wobei die genannte Auslöseelektrodenvorrichtung (36) einen Entladungsbogen an irgendeiner Kathode (26) in der genannten Vielfachanordnung auslösen kann, die sich auf einem geeigneten Potentialniveau befindet.

7. Die Kathodenvorrichtung gemäß Anspruch 6, die ferner eine lineare Zuführvorrichtung (61) einschließt, um wahlweise ausgewählte der Kathoden (26) in Richtung zu dem einen Ionenstrahl erzeugenden Ende (28) zuzuführen.

8. Die Kathodenvorrichtung gemäß Anspruch 6, die ferner eine lineare Zuführeinrichtung (62) einschließt, um die genannte Auslösekathode (42) in Richtung zu der genannten Vielfachanordnung wahlweise zuzuführen.

9. Die Kathodenvorrichtung gemäß Anspruch 6, in der die genannten Kathoden (26), die die genannte Vielfachanordnung bilden, im wesentlichen zueinander parallel sind, und wobei die Achse der Auslösekathode (42) in einer Ebene liegt, die im wesentlichen senkrecht zu der Achse der genannten Kathode (26) ist.

Revendications

1. Un dispositif (10) de génération de faisceau d'ions comprenant :

un carter (15) de forme générale tubulaire, fermé à la première extrémité par une première plaque (22) et à la seconde extrémité par une seconde plaque (16) ;

une pluralité de cathodes (26) à l'intérieur dudit carter, monté sur ladite première plaque (22), lesdites cathodes agencées dans un déploiement sensiblement parallèle, s'étendant vers ladite seconde plaque (16) ;

une anode (48) d'écran à transparence élevée, montée dans une ouverture dans ladite seconde plaque, ladite anode (48) s'étendant sensiblement parallèle audit déploiement de cathodes et sensiblement coextensible avec ledit déploiement ; et

au moins une cathode (38) de déclenchement et un assemblage (36) d'électrode de déclenchement positionnés adjacents audit déploiement et s'étendant dans ledit carter (15).

2. Le dispositif de génération de faisceau d'ions selon la revendication 1, incluant de plus des moyens (61) d'alimentation linéaire, pour alimenter sélectivement une desdites cathodes (26) sélectionnée vers ladite anode (48).

3. Le dispositif de génération de faisceau d'ions selon la revendication 1 ou la revendication 2, incluant de plus des moyens (62) d'alimentation linéaire, pour alimenter sélectivement ladite cathode (38) de déclenchement vers ledit déploiement.

4. Le dispositif de génération de faisceau d'ions selon une quelconque des revendications 1 à 3, dans lequel, ladite zone d'anode (48) d'écran a d'environ 30 à 75 % d'ouvertures.

5. Un dispositif de génération de faisceau d'ions selon la revendication 1, dans lequel, les extrémités (28), desdites cathodes formant ledit déploiement et s'étendant vers ladite seconde plaque (16), s'étendent sensiblement dans le même plan, et ledit assemblage (36) d'électrode de déclenchement est capable d'amorcer un arc à une quelconque desdites cathodes (26) sélectionnée.

6. Un assemblage de cathodes pour un dispositif de génération de faisceau d'ions, ledit assemblage de cathodes comprenant :

un déploiement de cathodes (26) semblables à des tiges, espacées, ayant chacune une extrémité (28) de production de faisceau d'ions ;

un assemblage (30) de cathode de déclenchement et d'électrode de déclenchement adjacent audit déploiement de cathodes ;

ledit assemblage (30) de cathode de déclenchement et d'électrode de déclenchement comprenant :

une cathode (42) de déclenchement en métal, semblable à une tige, s'étendant vers ledit déploiement ;

un manchon (44) isolant autour de ladite cathode (42) de déclenchement ;

un manchon (46) de métal autour dudit manchon (44) isolant ; et

une électrode (36) de déclenchement adjacente à ladite cathode (42) de déclenchement ;

grâce à quoi, ledit assemblage (36) d'électrode de déclenchement peut amorcer un arc à une cathode (26) quelconque dans ledit déploiement, qui est à un niveau de potentiel convenable.

7. L'assemblage de cathodes selon la revendication 6, incluant de plus des moyens (61) d'alimentation linéaire, pour alimenter sélectivement une desdites cathodes (26) vers ladite extrémité (28) de production de faisceau d'ions.

8. L'assemblage de cathodes selon la revendication 6, incluant de plus des moyens (62) d'alimentation linéaire, pour alimenter sélectivement ladite cathode (42) de déclenchement vers ledit déploiement.

9. L'assemblage de cathodes selon la revendication 6, dans lequel, lesdites cathodes (26) formant ledit déploiement sont sensiblement parallèles les unes aux autres et l'axe de cathode (42) de déclenchement s'étend dans un plan, qui est sensiblement perpendiculaire aux axes desdites cathodes (26).

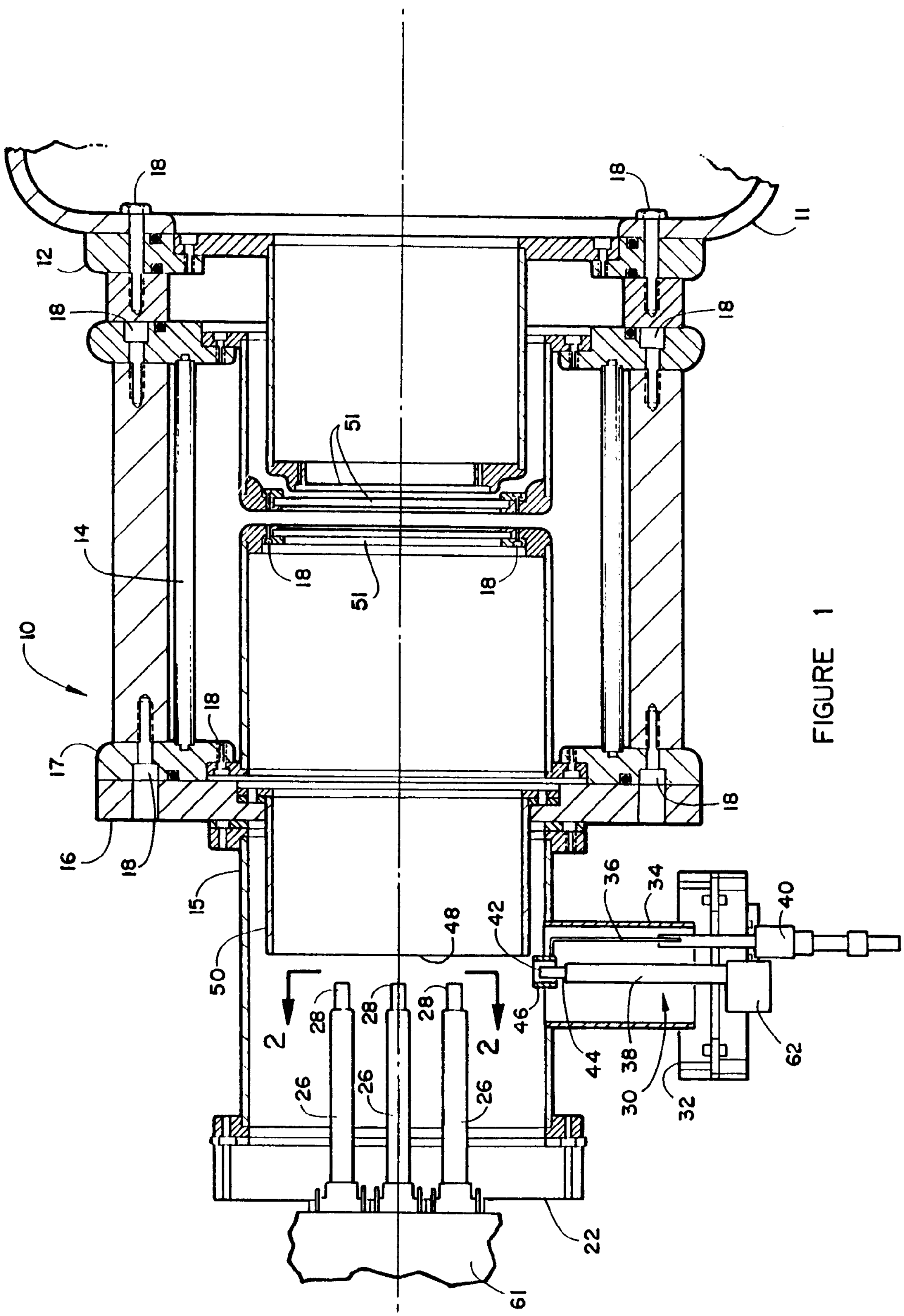
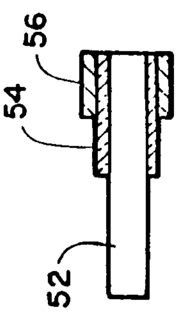

18
18
11
12
18
18
51
14
18
51
18
10
17
18
18
16
18
15
36
34
40
48
42
50
28
28
28
46
2
2
26
26
26
44
38
62
30
32
22
61

FIGURE 1



PRIOR ART
FIGURE 3

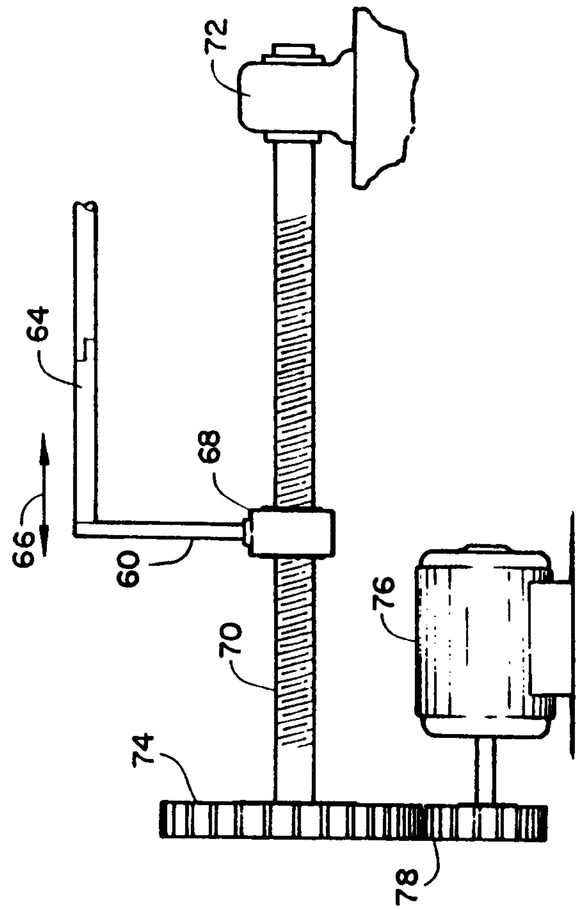


FIGURE 4

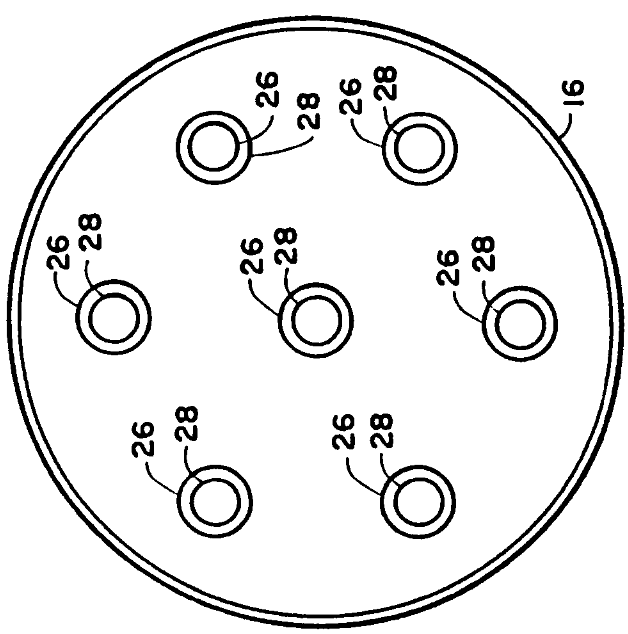


FIGURE 2